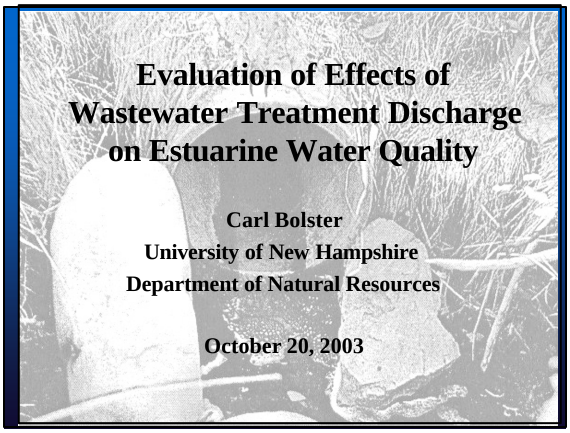

Evaluation of Effects of Wastewater Treatment Discharge on Estuarine Water Quality

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October 20, 2003

Project Participants

- Stephen Jones – Jackson Estuarine Lab
- Jonathan Bromley – UNH Grad student
- New Hampshire DES (Natalie Landry):
  - New Hampshire Estuary Program
  - Shellfish Program
- EPA
- New Hampshire and Maine Wastewater Treatment Facilities (WWTFs)

Project Goals

1. Assess the impacts of WWTF hydraulic overloading
   - Relationships between flow and rainfall

Project Goals

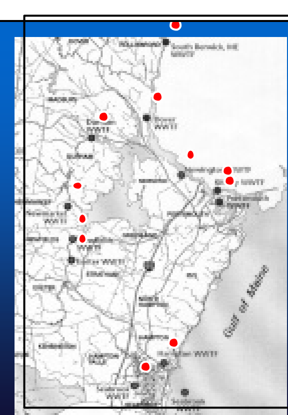
2. Estimate total fluxes of bacteria and nutrients (NH_4^+, NO_3^-, DON, TDN, DOC) from WWTFs
   - Standardization of indicator organisms between WWTFs (TC : FC : E. coli : Enterococci)
   - Monthly and intensive sampling
3. Preliminary analysis of relative risk of sewer infrastructure

Project Goals

4. Determine if regrowth of indicator organisms can occur in estuarine ecosystems

WWTF Sample Locations

- Monthly sampling at 11 WWTFs discharging to estuarine/marine waters
  - Dover, Durham, Exeter, Hampton, Newfields, Newington, Newmarket, Portsmouth and Seabrook (9 NH WWTFs)
  - Kittery and South Berwick (2 ME WWTFs)



Methods

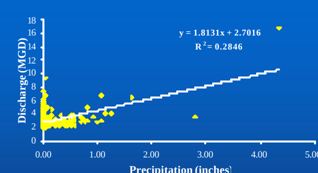
- Assessment of hydraulic overloading from rainfall events (MORs vs. Rainfall Data)
- Monthly sampling of 11 WWTFs for bacteria and nutrient constituents of concern
- Daily and weekly intensive sampling of WWTFs for bacteria and nutrient parameters
- Review/creation of GIS coverages and maps

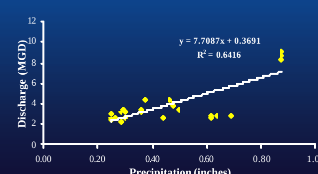
Analytical Parameters

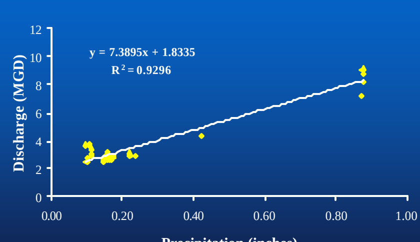
- Bacteria Analyses
  - Fecal Coliforms (mTEC)
  - *Escherichia coli* (mTEC)
  - Total Coliforms (mEndo)
  - Enterococci (mE)
  - Injured Coliforms (mT7)
- Nutrient Analyses
  - Ammonium (NH_4^+) –
  - Nitrate (NO_3^-)
  - Dissolved Organic Nitrogen (DON)
  - Total Dissolved Nitrogen (TDN)
  - Dissolved Organic Carbon (DOC)

Question 1:

- Is there a relationship between WWTF discharge and precipitation?







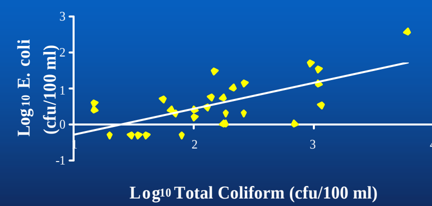
Results:

- Some seasonal relationships exist between precipitation and plant discharge
- No relationship was observed between plant discharge and concentrations of indicator organisms

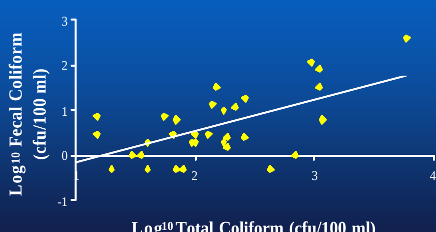
Question 2:

- Do relationships exist between the different indicator species used in WWTFs located within the GBE?

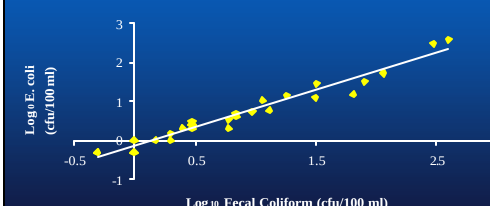
Indicator ratios



Indicator ratios



Indicator ratios



Results:

- Weakest relationship exists between total coliforms and fecal coliforms
- Strongest relationship exists between *E. coli* and fecal coliform concentrations

Question 3:

- How much variability exists in WWTF effluent?
  - Indicator organisms and N species
  - Monthly, weekly, and daily sampling

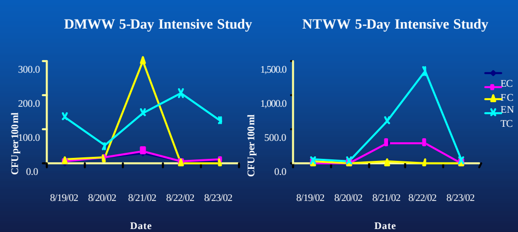
Monthly Variability
Durham WWTF

	Max	Min
EC (cfu/100ml)	101	BDL
FC (cfu/100ml)	32.5	BDL
TC (cfu/100ml)	210	40
TDN (mg/L)	22.6	5.0
NO_3^- (mg/L)	10.4	0.63
NH_4^+ (mg/L)	17.8	0
DON (mg/L)	18.1	BDL
DOC (mg/L)	14.6	5.1

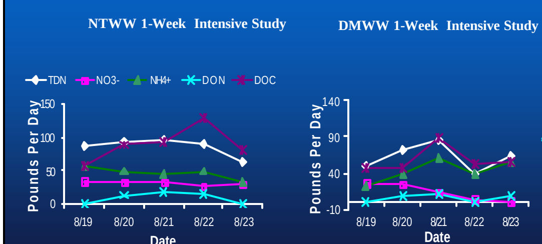
Monthly Variability
Newington WWTF

	Max	Min
EC (cfu/100ml)	0.5	BDL
FC (cfu/100ml)	2	BDL
TC (cfu/100ml)	84	BDL
TDN (mg/L)	21.8	2.0
NO_3^- (mg/L)	11.3	0.16
NH_4^+ (mg/L)	21.3	0.14
DON (mg/L)	14.7	BDL
DOC (mg/L)	22.9	9.62

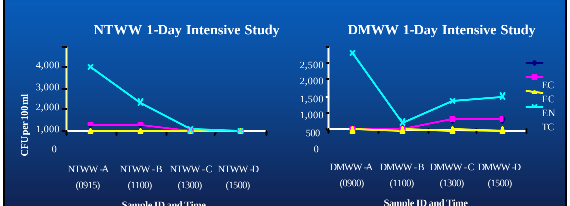
Daily bacteria concentrations



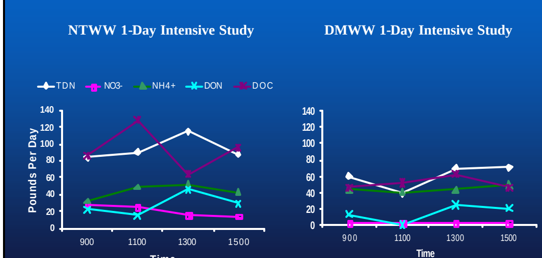
Daily N concentrations



Hourly bacterial concentrations



Hourly N concentrations



WWTF Identification	Nutrient Constituent (lbs per day)				
	TDN	$N\text{-}NO_3^-$	$N\text{-}NH_4^+$	DON	DOC
Durham	130.23	75.59	45.70	13.28	98.51
Dover	335.54	112.66	196.51	94.82	220.03
Exeter	134.27	38.89	98.66	14.95	132.60
Hampton	424.18	**280.78**	7.17	128.76	163.17
Kittery	73.80	42.69	29.77	15.29	65.99
Newington	11.79	2.84	8.86	2.18	13.01
Newmarket	90.87	19.32	70.67	26.85	98.09
Portsmouth	**574.79**	7.24	**466.88**	**273.89**	**1353.44**
South Berwick	17.22	6.83	11.05	1.02	17.81
Seabrook	94.94	66.38	25.18	29.02	73.44
Total Loading	**1887**	**653**	**960**	**600**	**2236**

N findings

- Ammonium seems to be the most frequent nitrogen species present in effluent
  - NH_4^+ is the most abundant nitrogen species in 8 of the 10 WWTFs sampled
  - Concentrations ranged from BDL to 18.29 mg/L
- WWTFs contribute to DOC concentrations
  - Concentrations observed from 3.72 mg/L to 36.54 mg/L

Bacteria Loading

- Significant variability in concentrations
- No consistent ratios between indicator bacteria
- Difficult to estimate bacterial loads to GBE

Maximum in-stream bacterial concentrations following dilution

	Durham	Dover	Exeter	Hampton	Kittery	Newington	Newmarket	Portsmouth	S. Berwick	Seabrook
EC	41.9	0.15	14.2	6.0	4.5	BDL	0.6	4.3	BDL	0.03
FC	13.5	0.64	15.3	13	6.5	BDL	0.11	1.6	BDL	0.04
EN	4.2	0.15	2.0	1.5	3.1	0.4	0.44	0.31	BDL	0.01
TC	87.5	2.1	229	430	79	0.8	20.8	21.8	0.93	2.1

Freshwater A Beach – 88 *E.coli* Tidal recreational – 104 enterococci

Approved shellfish – 40 fecal coliforms

Question 4:

- What towns are at greater risk for contributing bacterial contamination to shellfish growing waters from leaking infrastructure?

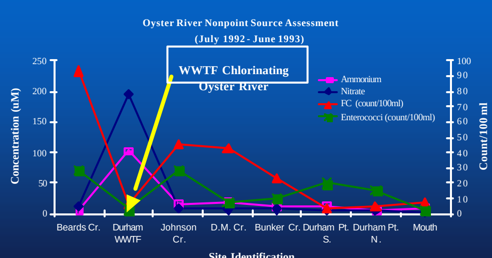
Approach

- GIS coverages were used to create 300 ft buffers around waterways feeding into GBE
- Length of infrastructure in buffer zones was determined for each town
- Number of stream crossings were determined
- Distance to shellfish beds was calculated
- Age of infrastructure was obtained from towns

Town	Length (ft)	# stream crossings	Distance (ft)	Age	# CSOs	Relative Risk
Durham	55,500	42	3,000	1955 – 1965	0	Medium /High
Dover	143,400	55	30	1973 – 1991	0	High
Exeter	37,700	21	25,000	1962	2	Low
Hampton	73,200	29	850	1964	0	High
Kittery	24,500	4	14,000	1968 – 1969	0	Low
Newmarket	20,900	15	8,800	1980 – 1990	0	Medium
Newfields	600	0	8,000	1982	0	Low
Portsmouth	82,200	17	7,000	1800s - current	3	High
Seabrook	63,400	29	400	1996	0	High
S. Berwick	82,200	16	18,000	1900-72	0	Medium

Question 5:

- Do chlorinated bacteria recover in streams?

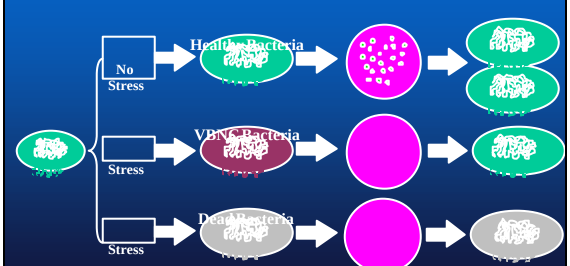


(Adapted from Jones and Langan 1993)

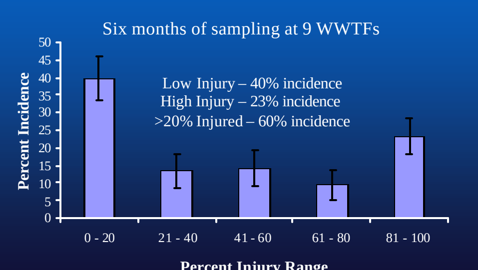
The VBNC State

Bacteria can maintain metabolic activity, but are unable to undergo sustained cellular division required for growth in or on a medium that normally supports growth of that cell (Oliver 1993).

The VBNC State



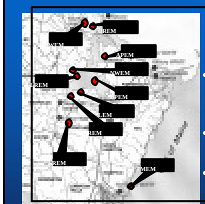
Results – Assessment of WWTF Effluent

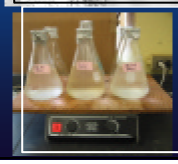


Implications of Injury

- Overestimation of bacterial death
- Resuscitation from a nonculturable state
- Maintenance of virulence

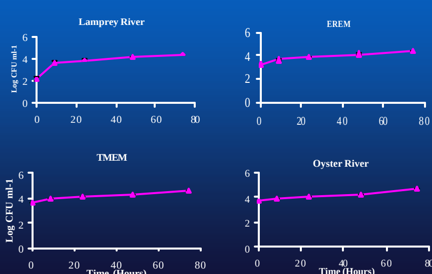
Methods



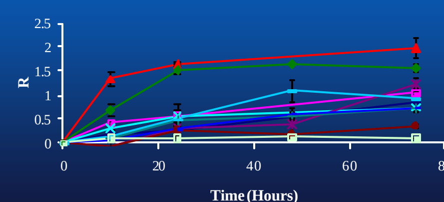


- Collected 5-liter samples from 10 estuary location (10 EMs); pH, salinity and nutrients analyzed
- Inoculated EMs with a chlorinated cell suspension in duplicate
- Stored at 20ºC in the dark for 74 hours – samples collected at 0, 10, 24, 48, 74 hours.
- Bacterial culturability and viability determined

Results – Microcosm Comparative Enumeration



Recovery in Estuarine Microcosms Over Time



R_{74} in Estuarine Microcosms

Estuarine Microcosm Identification	R_{74}
OREM	0.85
TMEM	1.06
LREM	1.98
EREM	0.75
CLEM	1.23
APEM	0.36
NWEM	0.72
BPEM	0.75
SREM	0.94
DWEM	1.57
CONTROL	0.08

EM Environmental Conditions

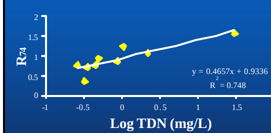
EM	Environmental Parameter						
	pH	Salinity (ppt)	TDN (mg/L)	$N\text{-}NO_3^-$ (mg/L)	$N\text{-}NH_4^+$ (mg/L)	DOC (mg/L)	$P\text{-}PO_4^+$ (mg/L)
OREM	7.4	0.7	0.87	0.29	0.12	7.01	27.7
TMEM	6.2	5.5	2.22	ND²	0.16	8.38	203
LREM	7.4	0.0	0.42	0.16	0.046	6.64	6.18
EREM	7.3	0.0	0.45	0.19	0.045	7.53	7.83
CLEM	ND	0.2	1.04	ND²	0.40	7.91	51.7
APEM	ND	10.5	0.33	ND²	0.067	4.40	26.9
NWEM	7.5	0.1	0.36	0.13	0.041	6.16	3.57
BPEM	7.4	5.9	0.27	0.03	0.062	4.97	4.56
SREM	7.6	0.7	0.49	0.14	0.14	7.75	1.34
DWEM	7.8	1.3	30.15	0.16	19.0	40.1	87.8

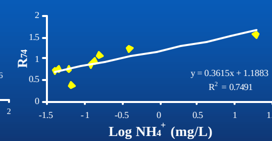
R_{74} vs. EM Environmental Conditions

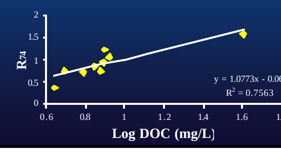
Simple Linear Regression Analysis Data

Environmental Parameters	R^2	p-value
pH	0.0127	0.8101
Salinity (ppt)	0.2516	0.1690
$\log_{10}$ TDN (mg/L)	0.7480	0.0026
$\log_{10}$ N-NH_4^+ (mg/L)	0.7491	0.0026
$\log_{10}$ N-NO_3^- (mg/L)	0.0444	0.6885
$\log_{10}$ DOC (mg/L)	0.7563	0.0023
$\log_{10}$ P-PO_4^+ (mg/L)	0.2124	0.2119

Results – EM Environmental Conditions Vs. R_{74}







EM Environmental Conditions vs. R_{74}

Backward Multiple Linear Regression Analysis Data

Variables Included in Model (p-values)	b	Squared Semi Partial	Model R^2	p-value
$\log_{10}$ DOC (0.002)	0.870	0.757	0.756	0.002
$\log_{10}$ DOC (0.034)	0.585	0.242	0.856	0.008
$\log_{10}$ N-NH_4^+ (0.068)	0.468	0.155		

Summary

- An underestimation of viable bacteria in WWTF effluent occurs on a regular basis.
- Nutrients discharged from WWTFs **may** contribute to regrowth regrowth/resuscitation of bacteria in estuaries

Management Implications

- Minimize introduction of bacterial populations to surface water
- Improvement and implementation of detection methods
- Decrease nutrient inputs to estuarine surface waters – minimize potential for nutrient-related resuscitation.
- More research is necessary to understand the significance of resuscitation in estuarine environments – effects of salinity, light, protozoan grazing.

Questions?